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THE USE OF FIRE IN THE PROTECTION OF LONGLEAF AND SLASH PINE FORESTS

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The southern Coastal Plain during the late winter and early spring of 1943 suffered one of the worst fire seasons in the experience of organized forest fire protection in this region; losses in the first 4 months of 1943 were approximately double the average annual loss for the past 8 years. Fire losses were particularly severe in the longleaf and slash pine portion of the Coastal Plain because of the long drought, large number of fires, and shortage of experienced labor for fire control.

Forest land owners and managers in the region of longleaf and slash pines are faced with a critical protection problem; recurrence of these severe conditions threatens the destruction of all or most of the growing stock on individual properties. In this situation, they are becoming increasingly interested in the use of fire as an aid to forest protection.

This use of fire has been developing slowly for several years; the very destructive fires of 1932 and 1934 led several forest managers in various parts of the longleaf pine belt to try winter burning to reduce hazardous fuel accumulations. Since then many properties have been so treated, first experimentally, then regularly, especially in south Georgia and northeast Florida where many leaders recognize this use of fire as a substantial aid to the successful management of slash and longleaf pine forests.

Misunderstanding and confusion obscure this practice, partly as a result of the term "controlled burning"—a loosely defined phrase which has widely divergent meanings to different people. Further confusion has been created by the criticism of those who, opposed to any use of fire in forestry, have strongly condemned it. Finally, the objectives, dangers, and full potentialities of this tool in forest management have not been clearly recognized by those using fire in forest protection, with the result that some burning has been either ineffective or definitely harmful.

This paper is prepared for the owners and managers of forest land on which the growth of forest products is the main objective. Its purpose is to present a preliminary guide for the improvement of current practice in the use of fire in forest protection. It is based on intensive studies of the behavior and effects of forest fires in these types, following several years of experimenting with the use of fire, and on the advice and experience of many operators and owners who are currently using fire in forest management.

FIRE PROTECTION

Woods burning in this region began with the Indians and was continued as a form of forest culture by the white civilization which followed. While timber was of little value, the forests were used principally for grazing and hunting; fire improved these forest uses. Woods burning is still practiced promiscuously, although now the value of the timber resources usually greatly exceeds other uses of the land. Fires here are so common that of the area burned over in the United States, about nine-tenths is ordinarily reported from the 11 Southeastern States.

Forest fires in the longleaf and slash pine forests have extremely high rates of spread, frequently burning 100-250 yards per minute in the direction of the wind. These high rates are explained by the openness of the stands, permitting high wind velocities near the ground, and by the erect, dense, herbaceous fuel, permitting flash combustion. Fires are frequently large before suppression can be started.

Both longleaf and slash pine, the important trees of this region, are fire resistant. The remarkable ability of longleaf pine to survive and grow in spite of repeated burning accounts for the formerly extensive virgin forests of this species. In the first year longleaf seedlings are easily killed, but the buds of older seedlings are protected by plumes of resistant needles, and the vital cambium of older trees is protected by a thick bark of low conductivity. Slash pine, although readily killed by light fires as a small seedling, is much more fire resistant than was formerly supposed. It soon develops a thick bark and from the sapling size onward approaches longleaf pine in its resistance to fire.

In southern Georgia and northeastern Florida freedom from fire for a few years usually results in dense stands of thrifty slash pine reproduction along swamp margins and in other localities where seed supply is abundant. Longleaf pine reproduces less successfully because of infrequent seed years, damage by hogs, and delayed height growth; where both are found in association, slash pine is now usually ascendant.

With the extension of young slash pine, the difficulties of forest protection increase. The high grass rough1/ remains while undergrowth increases and needle litter accumulates. Wildfires become more difficult to control, and a rising threat to the valuable reproducing stands. This trend continues indefinitely in such stands, leveling off only after about 20 years of fire exclusion.

In the northern and western parts of this forest region, slash pine is scarce or absent. Here the original longleaf pine forest has in many places been succeeded by shortleaf and loblolly pines and hardwoods during the past 50 years. This latter type has a litter fuel which, together with a lowered wind movement resulting from the denser stands, greatly simplifies forest fire protection. There is little or no evidence supporting the use of fire in protecting this forest type.

Over much of the region, however, main dependence for future stands must rest on longleaf pine. With this species freedom from fire is necessary in the year following seedfall, while wildfires of ordinary intensity are undesirable in all reproduction. Long periods of fire exclusion, however, have been found hazardous in growing longleaf pine. Fuels accumulate steadily for 20 years or more in fully stocked stands. Fires during the latter part of this period may completely destroy thrifty second-growth stands as at Urania, La., in 1932.2/

1/ Rough: An accumulation of all living and dead herbaceous vegetation, especially grasses, and forest litter sometimes with the addition of underbrush, such as palmetto, gallberry, and waxmyrtle. The term is most often used to designate the ground cover of longleaf and slash pine forests when unburned for 1 or more years.

2/ Bickford, C. A., and Henry Bull. A destructive forest fire and some of its implications. Southern Forest Experiment Station, Occasional Paper 46, 4 pp. Apr. 15, 1935.

On lands reproduced to longleaf pine, periodic burning to reduce fuel accumulations and to control brown-spot has been widely recommended and occasionally used. The high fire tolerance of this species makes such use of fire neither difficult, costly, nor hazardous.

USE OF FIRE

Forest managers in the Southeast attempt to exclude fire completely until slash pine attains a height of 5 or more feet. From this point, practice varies; some continue a fire exclusion policy; others, in the fear of extreme losses arising from the associated accumulations of fuel, are burning under conditions selected to minimize damage to these young stands.

Farther west and north in the longleaf-slash region, where slash pine is less common, owners of forest land have used fire less frequently. The more open stands are less likely to produce dangerous fuel accumulations and use of fire there is more silvicultural than to assist in or to simplify forest protection.

The development of fire as a tool in forest management has come about gradually. First was the realization by some forest owners and managers that certain fires, or parts of fires, resulted in little or no damage to the forest. This was followed by the recognition that fire of the less injurious variety might be good forest management if confined to appropriate areas. Next came the definition of several valid uses of fire in forest management: seedbed preparation, control of the brown-spot needle disease, undergrowth reduction, and reduction of accumulated fuels to aid fire protection and to insure young fire-sensitive stands. Finally, R. M. Conarro[3] pointed out that each use of fire has one dominating motive and that appropriate burning specifications may vary widely, depending upon this motive. Following this reasoning, Conarro developed the concept of "prescribed burning" where fire is used only for certain recognized purposes and on lands where these uses are valid. As the term implies, a unit where fire use seems suitable is studied carefully to determine the appropriate fire treatment needed to meet the dominant motive. This study, or diagnosis, is followed by the "prescription" which specifies where, when, and how to burn to accomplish the objective.

The proper use of fire is thus seen to consist of three steps: analysis, planning, and execution. The analysis defines the purpose and weighs advantages against disadvantages; where anticipated costs and losses are greater than probable benefits, fire should not be used. The plan defines the area to burn and the time and manner of burning needed to fulfill the purpose with as little injury as possible to the stand. And, finally, the area is burned, following the plan as closely as circumstances permit.

A discussion of both the obstacles and the advantages of fire use follows, with a suggested form of analysis to arrive at a sound conclusion on the use of fire.

Obstacles

The major obstacles to fire use are: damage to timber resources, expense of burning, mixture of sizes in present stands, and possibly unfavorable public reaction. Damage includes the killing of smaller trees, reduced growth, creation or enlargement of bole injuries, and impairment of the soil; some damage in one or more of these forms is an inescapable part of using fire extensively.

3/ Conarro, Raymond M. The place of fire in southern forestry. Jour. Forestry 40 (2): 129-131. Feb. 1942.

Fires of low intensity kill virtually all longleaf pine seedlings during their first growing season and many slash pine less than 5 feet in height. Fires of moderate intensity kill numerous slash pine 5-20 feet in height and longleaf pine $\frac{1}{2}$-5 feet in height, especially when attacked by brown-spot. Larger pines usually survive all but the most severe fires.

Such fires often kill all the needles and actually consume a portion of them by spot crowning; where this occurs, buds are killed too and the tree dies in many cases. This mortality is an important aspect of the damage caused by severe fires. Badly scorched trees, especially in late spring, summer, and early fall fires, are frequently attacked by Ips beetles. Epidemic infestations following severe fires may result in complete killing of entire stands.

In prescribed burning, losses in growth resulting from defoliation of the trees by the heat of the surface fire may be important. Loss of one-third or less of the foliage of these pines normally results in no measurable loss of growth. Complete browning of the needles, on the other hand, commonly results in losses equivalent to about 1 year's normal growth—this loss being distributed over about 3 years with 6/10 in the first, 3/10 in the second, and 1/10 in the third year following the fire. Losses in growth from intermediate degrees of heat defoliation are roughly proportional to the degree of defoliation.

Although fire alone rarely creates scars on these pines, on a wounded tree it may produce important damage by enlarging and extending the injury. This is particularly evident in burned turpentined woods where fire accelerates the destruction of worked-out trees by progressively weakening the lower boles until they become windfalls. The turpentine borer is especially destructive when the protective coating of hardened resin is burned from a face.

Stands that have been utilized for naval stores may suffer important damage from use of fire. Good forest management requires reasonably continuous working until utilization is complete, and the prompt removal of worked-out trees. It is common, however, to find trees with both working and worked-out faces throughout timber stands in the naval stores belt. Fire use in such stands is expensive because of the injury to these faces if not raked carefully and because of the high costs of raking. Damage in such stands may include breakage at the face, degrade, reduced volume, and, on trees being worked, lowered quality and quantity of gum production and destruction of cups and gutters.

Practices in preparing such stands for prescribed burning vary and definite recommendations to cover all cases cannot be made. All working faces are customarily raked before burning. Resting unburned faces are usually raked also, and this is considered good practice. Worked-out unburned timber will be weakened and will suffer considerable degrade in burning and may often be profitably raked, especially where the timber is to remain standing for several years. Burned worked-out timber will ordinarily not be raked. In treating a turpentined stand the various losses which may occur in burning should be weighed against the advantages of burning and the costs of raking to determine the most economic stand treatment.

The influence of burning on the soil has been studied by Heyward and Barnette[4] and others. This work has shown a small improvement in the chemical properties of the soil as a result of burning, while the physical properties have

4/ Heyward, Frank, and R. M. Barnette. Effect of frequent fires on chemical composition of forest soils in the longleaf pine region. Fla. Agr. Expt. Sta. Tech. Bull. 265, 39 pp., illus. Mar. 1934.

been slightly impaired. In general, the research on this subject gives no strong reasons either for or against the use of fire; further work may detect other damages that are now obscure.

Accidents, failures, and errors in burning operations are the principal sources of damage. Injury is usually present wherever fire is used but the most damage occurs on areas that were burned more severely than was intended for various reasons, such as changes in wind direction or through failure to prepare a strategic line, or mistakes in setting the fire. The most common damage results from wind variations over which the burner has no control.

The importance of wind in using fire can hardly be overemphasized. A shift in direction of more than 90° converts a backfire into a headfire; a lull, when burning in young stands, may increase defoliation tenfold because the heat, which was being largely dissipated, rises vertically to scorch the crowns of the young trees, perhaps killing them. Accurate weather forecasts are seldom available and the burner, unable to control wind, must cultivate an ability to predict its behavior.

Costs are an important drawback to the use of prescribed burning in this region. Costs per acre decrease as the size of area and the age of the stand increase; increase as the age of the rough, stand density, increase. Shape of the area has an important bearing on costs, as have the amount of line preparation and the size of the crew. Where flank fire and occasional head fire can be used, burning will be much more rapid and less expensive than where back fire alone must be used. Weather conditions influence the spread of fire and consequently strongly affect cost. The presence of gallberry and palmetto increases difficulty of burning, and costs. Where there is little possibility of damage, burning can be done at very low costs. Where such damage may be appreciable and would be reduced by thoughtful planning and careful execution, such inexpensive burning may be poor management.

Stands vary widely in the damage possible under prescribed burning, and the justifiable costs in controlled burning vary through a similar range. Costs of as little as 1 cent an acre are possible under some conditions, while costs of 30 cents or more for areas of heavy rough and mixed sizes and conditions may occasionally be most economical.

The success of prescribed burning depends to a large extent on the development of economic techniques for accomplishing the desired objectives. Careful planning and the choosing of appropriate weather conditions for the burning should be relied upon rather than large crews to accomplish difficult burning chances.

Frequently, use of fire in forest protection, if planned with that end in view, will result, through the establishment of barriers, in a large measure of protection for an entire forest unit. In such cases, the cost of the operation is a proper charge against the whole unit and may amount to a small fraction of a cent per acre for the whole area. In any event, the cost per acre protected is a more significant figure than the cost per acre burned.

The mixed and patchy character of most stands is an important impediment to using fire, especially where slash pine is common. Theoretically it is only necessary to select areas that are easy to burn and proceed with the job; practically these areas are hard to find because of the boundless mixing of ages, sizes, turpentine faces, and species, sometimes in the same stand, sometimes separately by very small areas, and, only occasionally, separately by areas sufficiently

large to burn efficiently. This mixture of tree ages and sizes complicates an already difficult problem; in time, it may be simplified by following the principles of even-aged management. For the present, the exercise of careful, thoughtful judgment is imperative in choosing the areas on which fire may be used. This judgment should be guided by appraisals of probable effects of fire.

The least tangible disadvantage to using fire is the influence of such use on public opinion. It is a direct contradiction of much of the fire prevention propaganda that has been broadcast. For foresters to now make use of fire appears, to many who have actively worked on these campaigns, a distinct breach of faith and a reversion of policy which may result in discouragement and confusion. There is the danger too that use of fire by foresters may stimulate and extend the already promiscuous woods burning.

Use of fire in forest management may have a favorable as well as an unfavorable influence on public opinion. Many southerners who have long seen an advantage in fire use will be encouraged by the general recognition of this tool. Promiscuous fires may be reduced, at least to the extent to which prescribed burning meets the objectives of the promiscuous burner. Forest practice will be encouraged by the development of a practice which largely removes the possibility of large damaging fires.

Public reaction to the use of fire is at present unpredictable. Fear of unfavorable public reaction exists and is one of the strong deterrents to the use of fire in forestry.

Benefits

The benefits of using fire in forest management can be placed in two classes: those which facilitate forest protection and those which improve forest production and forest values. Protection is made easier by the reduction or temporary elimination of accumulated fuel resulting in a temporary elimination of wildfires and a lowering of their intensity over a longer period.

Burning for fire protection has its chief impetus in the desire of the forest land owner to escape from the catastrophe of complete forest destruction. At infrequent intervals and at various places throughout this belt a period of successful forest protection has been followed by a few large fires of extremely high intensity and destructiveness. The occurrences have sometimes resulted in the destruction of entire operations, and have been a serious drawback to the extension of private forest management. To the landowner controlling 20,000 acres or less in a block such fires are particularly threatening, for his whole investment might be wiped out in a single day. A program which minimizes the occurrence of such disasters should encourage the individual landowner, and, through him, result in the increase of forest management.

The most common benefit sought is the reduction of damage in young stands. Well-stocked stands of young slash pine are common in the Southeast on areas unburned for several years. Fuels accumulate rapidly in such stands to the point where fires crown under most burning conditions. Where the crop trees are 10 feet or more in height and not too dense, such a stand can be treated, under appropriate conditions, with insignificant losses to the growing stock. Burning under these conditions has an extremely high insurance value since, by the time the fuel reaccumulates, the stand will be much more fire resistant.

In denser stands in the Southeast the successful use of fire is often difficult and, as such stands offer profitable thinning chances, thinning and burning have often been combined, with burning following the thinning by a few days. The openness of the thinned stand permits the wind to dissipate the heat more effectively while the green debris from the burning reduces fire intensity. Some operators prefer to defer burning following thinning for a period of several months to a year to permit the partial decay of the debris.

The accumulation of fuels in older stands of these types is also a serious threat to their safety and development. Under the worst fuel and weather conditions, fire may kill the largest and most fire-resistant pines. Any wildfire in such fuels is likely to be highly injurious to the stand and especially to that portion exposed to the head fire. Burning to reduce the accumulated fuel provides a few months of absolute protection, and several years of progressively diminishing insurance from excessive damage. Removal of fuel accumulations results also in easier fire suppression which in turn should result in substantial savings in area burned and in damage. The normal build-up of fuels following a burn proceeds rapidly at first and then levels off at about 3 years in open stands where the fuel is mainly herbaceous to about 20 years in dense stands where the needle cast and other forest litter are important.

Burning to create barriers to fire spread and strips of thin fuel that permit direct attack on fires is a potentially valuable use which has been only partially explored. Most fire damage, under organized protection, comes from a few fires starting under unusually favorable burning conditions and spreading rapidly over thousands of acres before their spread is stopped. The burning of 5 to 10 percent of an area, in strategically located strips, can be of great value in reducing the size of such fires. These barriers or protective strips should usually be about 200-300 yards wide, continuous, and properly located with reference to critical winds; there should be some burning each year, but burning the same area in two successive years should be avoided. Such strips should result not only in reducing the size of the largest fires, and damage in proportion, but should also reduce the costs of fire suppression.

Burning to reduce accumulated fuel and to create barriers may also result in a small reduction in the number of wildfires. Fires due to carelessness should decrease about in proportion to the area burned. Wilfully set fires may be reduced to the extent to which the area treated also meets the objectives of the woods burner. Ordinarily, these motives will not be completely satisfied and fires from this source will continue.

The use of fire does not eliminate the need for an effective organization for fire control. By limiting the size of fires and reducing the difficulties of control, however, prescribed burning should theoretically reduce the fire control forces required in comparison with those needed when no use is made of fire. Practically, there may be no immediate reduction in protection costs, because of the present inadequacy of most fire control efforts.

Besides fire protection, there are several possible benefits to the use of fire in these types. Most such benefits apply, however, to limited areas and for short periods only. The most important benefits are in silviculture, grazing, game management, and in the use of fire to improve utilization. In general, using fire for one of these other purposes demands a special plan and justification. Frequently, however, fire used for protection will also provide certain silvicultural or other advantages which should be duly considered in analyzing the desirability of this practice.

The main silvicultural benefits from burning are improved seedbed, disease control, and reduction of weed species. Pine seeds germinate in greater numbers[5] and develop more rapidly when they fall in fresh burns; this advantage is small with slash pine but important in the regeneration of longleaf pine. Planting costs may frequently be decreased through burning. The brown-spot needle disease in stands of longleaf pine seedlings in the grass stage may be lowered by destruction of the infected foliage by fire. Burning to thin thickets of young slash pine has been suggested, but is not recommended because of the tendency of fires to kill trees in groups and because the trees killed by fire are commonly better crop trees than those left.

Control of weed species is important in the management of longleaf and slash pine forests, and fire used properly can be an effective agent in such control. The most important weeds are the various scrub oaks, but other woody shrubs and hardwood trees also tend to increase with prolonged fire exclusion. Fire alone will not halt the invasion of hardwoods, but repeated fire with shade of a pine overstory can be used to eliminate these species. Repeated burning for this purpose may result in some loss to the pine stand and should be used only after full analysis of both the advantages and disadvantages. The use of fire to control hardwood invasion is a complex subject; much remains unknown, but evidence supporting this use is promising.

Undergrowth frequently impedes utilization of the forest. Naval stores operators prefer burned woods because of the lowered costs of cupping, chipping, and dipping, and particularly because of the lessened risk of loss of gum, cups, and faces through wildfire. Turpentine workers have a strong aversion to snakes and prefer to work in burned woods which afford less cover for these reptiles. The harvesting of other forest products is also impeded by a dense ground cover and undergrowth. The partial cutting of pulpwood in rough woods, for instance, is often unattractive to contractors because of the difficulties of bucking, finding, and loading bolts.

Profits from livestock production as ordinarily practiced in this region are usually too small to attract the investment of private capital in unimproved land for this purpose. Grazing is, nevertheless, a locally important industry and burning of the range to improve forage for cattle and sheep is a recognized practice with established benefits. In tracts managed for forest products, grazing is often permitted or tolerated and may provide a significant part of the forest income. Forage plants in the pine types are progressively reduced by fuller stocking of trees and by fire exclusion; the effect of needle cast in smothering grasses is marked in dense stands. Periodic light fires commonly prolong the grazing resource on such areas. Plants growing on early spring burns are highly palatable over a short period; cattle herd on such areas and do well on the forage. Cattle owners prefer regular spacing of small burns every few weeks to the burning of an equal or larger area at one time. Burned areas are used to gather stock for such purposes as branding and shearing.

Fire, properly used, has also been found valuable in the management of wild land for quail and turkey.[6] These and other game may be benefited by the appropriate use of fire as developed by specialists in this field.

5/ A noteworthy exception results from the occasional concentration of seed-eating birds on fresh burns.

6/ Stoddard, Herbert L. The bobwhite quail. 505 pp., illus. New York, 1931.

ANALYSIS

A careful analysis in which the dominating motive is clearly defined and the expected costs and damages are weighed against the anticipated benefits should precede each use of fire. Such analyses focus attention on important elements, clarify the issue, and should prevent burning those areas where the disadvantages exceed the advantages.

Variations in fuel and stand conditions, in objectives of management, in fire occurrence and size, and in other factors make it desirable to appraise each forest unit separately in determining the desirability of using fire. Each element of cost, damage, and benefit should be estimated as accurately as possible and totaled, subtracting the expenses from the gains. Where the net result is negative, use of fire is improper and no further effort is needed. Where it is positive, however, there is a valid use of fire and the forest manager should proceed with the planning and burning.

In such an analysis three steps are recognized: (1) recognition of the purpose of the burn; (2) general comparison of advantages and disadvantages for the whole area influenced; and (3) specific analyses of proposed burning units.

The advantages and disadvantages of using fire have been previously discussed. To make the analysis, it is necessary to evaluate each for a specific property. Public reaction to the use of fire is an intangible impossible to evaluate, but it should be weighed against any positive net advantage resulting from an appraisal. Where the net advantage is small, unfavorable local reaction may veto the use of fire.

Another intangible is the risk of fire of unusually large proportions such as the Cogdell (Ga.) fire of 1934; similar large fires have occurred on the Osceola National Forest (Fla.) in 1932, 1941, and 1943. Such fires may spread over several thousands of acres in a few hours, wrecking the forest operation. The risk of such a fire on a particular property is difficult to evaluate, yet such risk is an important consideration in most instances of fire use.

The following assumed data illustrate a simple analysis:

Present situation:

Area protected	50,000 acres
Period of protection	10 years
Annual protection cost	\$5,000
Mean annual loss	3,000 acres
Mean annual damage	\$4,500
Fires over 1,000 acres in 10 years:	
Number	12
Total area burned	23,000 acres

Analysis of use of fire:
Purpose: reduction of damage from wildfires.
Area to burn: 5,000 acres.

Estimated costs (for 1 year):

Ordinary damage from using fire	\$ 200
Extraordinary damage due to accidents, mistakes, etc.	600
Costs of burning	1,000
Subtotal	\$1,800

Estimated benefits (for 1 year):

Reduction in damage from wildfires	\$2,000
Reduction in suppression costs	300
Other benefits	250
Total	\$2,550

The above analysis shows a net advantage of $750 for the use of fire. The analysis is not complete, however, without weighing two intangibles, one an advantage, the other an obstacle. Fire use decreases to a marked degree the possibility of a fire of large size and high intensity on the area treated. On the other hand, use of fire may have an unfavorable public reaction, resulting in more fires and more damage. Unguided judgment must be relied upon at present in evaluating these important factors. One or the other of these intangibles will frequently be the deciding influence in arriving at a local policy.

Such analyses can never provide complete and positive answers to the wisdom of the practice. They provide, however, for proper consideration of each important factor and are the proper basis for decision.

PLANNING

Where the analysis has established the desirability of using fire, the next step is planning the burn to accomplish the dominant objectives with a minimum of injury to the stand. The plan should specify the exact area, the most appropriate time, and the most efficient manner of burning, considering the particular requirements of the stands and the attendant costs.

Area To Be Burned, and Pattern

Early in planning, a decision should be made on the amount of area to be burned and its location. Decision on these points must be governed mainly by such local considerations as distribution of age classes, amount of labor available, and previous occurrence of fires, but there are a few principles of general application which should be considered in all planning.

The size of the area to be treated by fire in any one year is frequently confined by such practical considerations as the amount of manpower and equipment available and by the length of the burning season. Those who use fire in forest management frequently fail to treat the area planned because of unfavorable weather conditions or scarcity of labor, or both. It is unwise, however, to plan on too extensive treatment in any single year. One reason is the desirability of continuous fire use, while the cost involved in treating a large proportion of the area in a single year is another. The area treated in a single year should rarely exceed 15 percent while burning as little as 7 or 8 percent of the area may prove most efficient. An exception might be made in the first years of using fire after a long period of fire exclusion when extraordinary measures might be adopted to reduce all heavy fuel accumulations within a period of 3-5 years. A rotation of fire treatment of 7-18 years should, however, prove most efficient after this initial period of fuel reduction.

Distribution of burned areas is important because of the influence which recently treated areas have on fire spread and on fire suppression. Most burning for fire protection to date has had for its primary purpose fuel reduction to provide insurance against destructive wildfires. Burning operations for this purpose alone are frequently justified, but an obvious advantage exists in burning so as to form more or less continuous strips, thus blocking the unit into areas surrounded by wide fire barriers[7] effective for several months after the burning operations. Planning burning operations so as to make such barriers is strongly recommended.

7/ In this paper, "barrier" has been used to describe wide strips of freshly burned areas, while "break" has been used for narrower strips (e.g., plowed lines, roads, small streams, etc.).

Barriers to be effective should be wide enough to stop the head of severe fires. Necessary widths under bad fire weather are unknown, but a width of from 8 to 10 chains is probably the minimum which should be considered for these types. For a given area treated, the wider the strips, the fewer will be possible, so strips of the minimum width necessary to stop severe conflagrations are desirable. A strip 8 to 10 chains wide can ordinarily be burned out easily under control in a single work period and may be a convenient width if found to be sufficiently wide to serve as barriers.

Barriers to be reliable should be reasonably continuous. Continuity in burning is made difficult by the presence of swamps and ponds which cannot be treated and by the presence of reproducing areas below the age and size of safe burning. To overcome these difficulties, strips can frequently be meandered around such obstructions. In addition, strips may be widened into zones in districts where patchy reproduction occurs, with the burning confined to the older age classes.

Location of barriers in relation to the prevailing wind directions during the fire season is important. It is recognized that a barrier is most effective against a fire burning to it at an acute rather than at a large angle. If a wind direction common to bad fire days can be recognized, barriers should be planned to run at an angle of 60° or less to such direction.

Pattern of burning will frequently be influenced by large areas in the reproducing sizes, and by many other local considerations such as areas of heavy fire occurrence. The first step in planning, however, should be to lay out on a map of the unit a desirable distribution of areas to be burned, using only the general information on stand conditions available to the forest manager. With this general plan, the selection of definite areas or units for burning can be undertaken by field examination. A general pattern of burning is shown in figure 1.

Selection of Burning Units

The next step in planning is the preliminary adjustment of the pattern to fit conditions in the woods, locating burning areas to minimize injury while preserving the general scheme. To do this efficiently, it is necessary to classify the area on fuel and stand conditions and to set up burning units that fill out the design.

The following classification is recommended: (1) unburnable areas (ponds, lakes, and other areas on which fire will not spread); (2) areas which must not be burned because of stand conditions; (3) areas difficult or expensive to burn; and (4) areas easy and inexpensive to burn. Areas difficult and expensive to burn are often those in greatest need of treatment and should not be omitted or deferred on the basis of difficulty and expense alone. The main elements which define these classes are: the fuel, its composition, arrangement, and amount, stand density, and the species and size of crop trees. Table 1 has been prepared as a guide to stand classification.

Fig. 1. Proposed pattern of burning for 13,000-acre block in the Louisiana Coastal Plain (after preliminary survey).

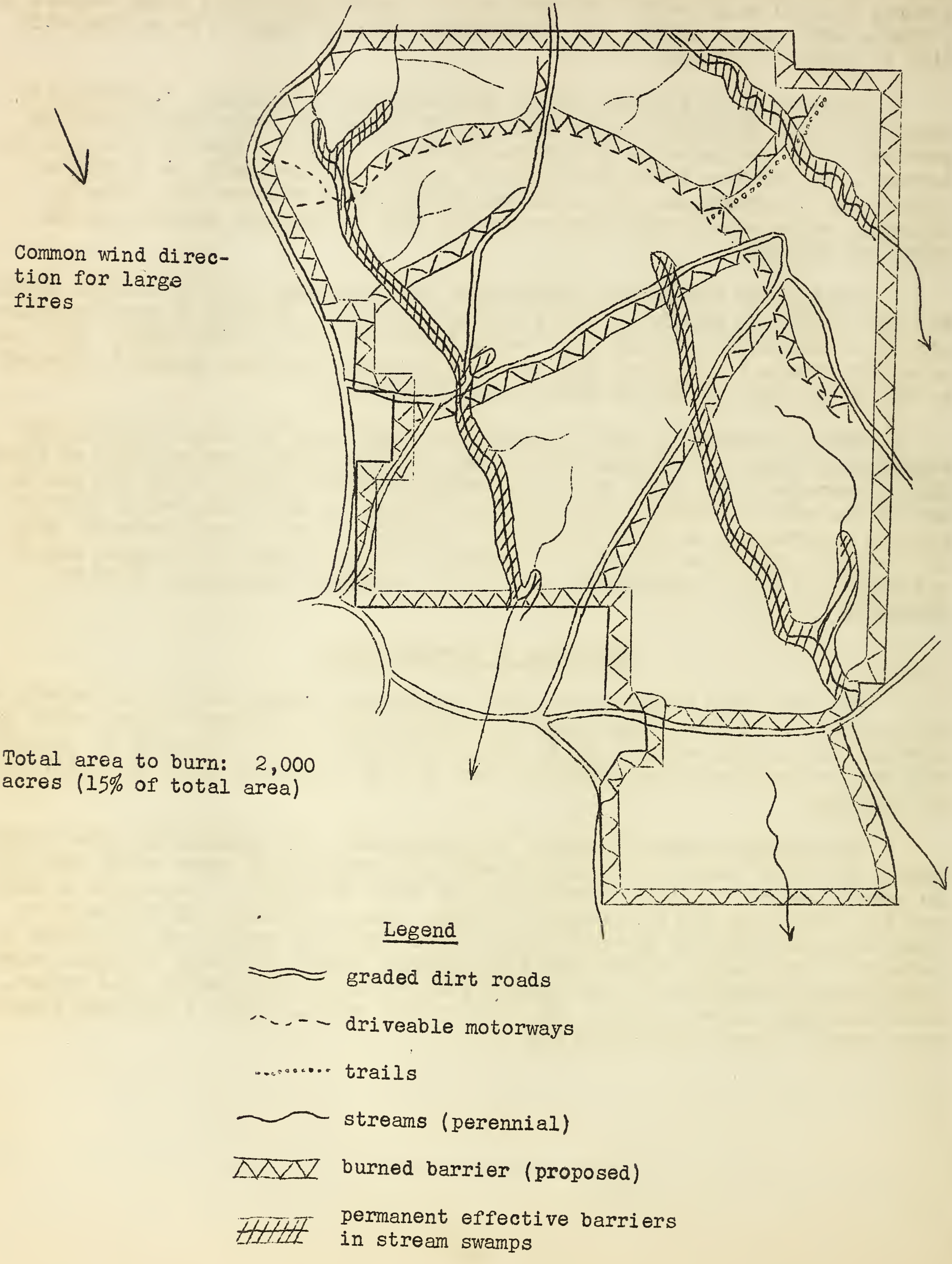


Table 1. - Fuel and stand classes for using fire.

Species of crop tree	Fuel	Pine density	Palmetto	Crop trees							
				Age	Size (age 2 or more) Height						d.b.h.
				Less than 1	0'-1'	1'-5'	5'-10'	10'-15'	15'-20'	20'-4"	4"+
				Fuel and stand classes c/							
Longleaf pine	Draped litter fuel a/	Open	Present	0	0	0	0	0	0	0	0
			Absent	0	0	0	0	0	0	0	0
		Dense	Present	0	0	2	2	2	2	3	3
			Absent	0	0	0	2	2	2	3	3
	Undraped litter fuel b/	Open	Present	1	0	0	0	0	0	3	3
			Absent	1	0	0	0	0	0	3	3
		Dense	Present	1	0	0	2	3	3	3	3
			Absent	1	0	2	2	3	3	3	3
	Grassy fuel	Open	Present	1	3	2	2	3	3	3	3
			Absent	1	3	2	2	3	3	3	3
		Dense	Present	1	3	2	2	2	3	3	3
			Absent	1	3	2	2	3	3	3	3
Slash pine	Draped litter fuel	Open	Present	1	1	1	1	2	2	2	3
			Absent	1	1	1	1	2	2	2	3
		Dense	Present	1	1	1	1	1	2	2	2
			Absent	1	1	1	1	1	2	2	3
	Undraped litter fuel	Open	Present	1	1	1	1	2	2	2	3
			Absent	1	1	1	2	2	2	3	3
		Dense	Present	1	1	1	1	2	2	2	3
			Absent	1	1	1	1	2	2	3	3
	Grassy fuel	Open	Present	1	1	1	1	2	2	2	3
			Absent	1	1	1	2	2	2	3	3
		Dense	Present	1	1	1	1	2	2	2	3
			Absent	1	1	1	2	2	2	2	3

a/ Draped litter fuel: Needles of pine conspicuously present on shrubs and lower limbs, frequently in such amounts as to partially smother low shrubs.

b/ Undraped litter fuel: Needles confined principally to bed on the ground.

c/ Fuel and stand classes: 0 - ordinarily does not occur. 1 - do not use fire. 2 - difficult or expensive to burn properly. 3 - easy and inexpensive to burn properly. The presence of 10 or more unburned turpentine faces per acre makes an area, otherwise easy and inexpensive, difficult or expensive to burn.

A burning unit is an area of such size and shape that, considering its fuel, stand, and burning conditions, one crew can burn it properly in one work period (8-12 hours). These units will vary in size over a wide range depending on fuel and stand conditions, reasons for burning, objectives of management, and size of crew. Each such unit should be surrounded by adequate firebreaks (i.e., plowed lines, streams, swamps, or other obstacles to spread) and should be burnable with a reasonably uniform fire intensity.

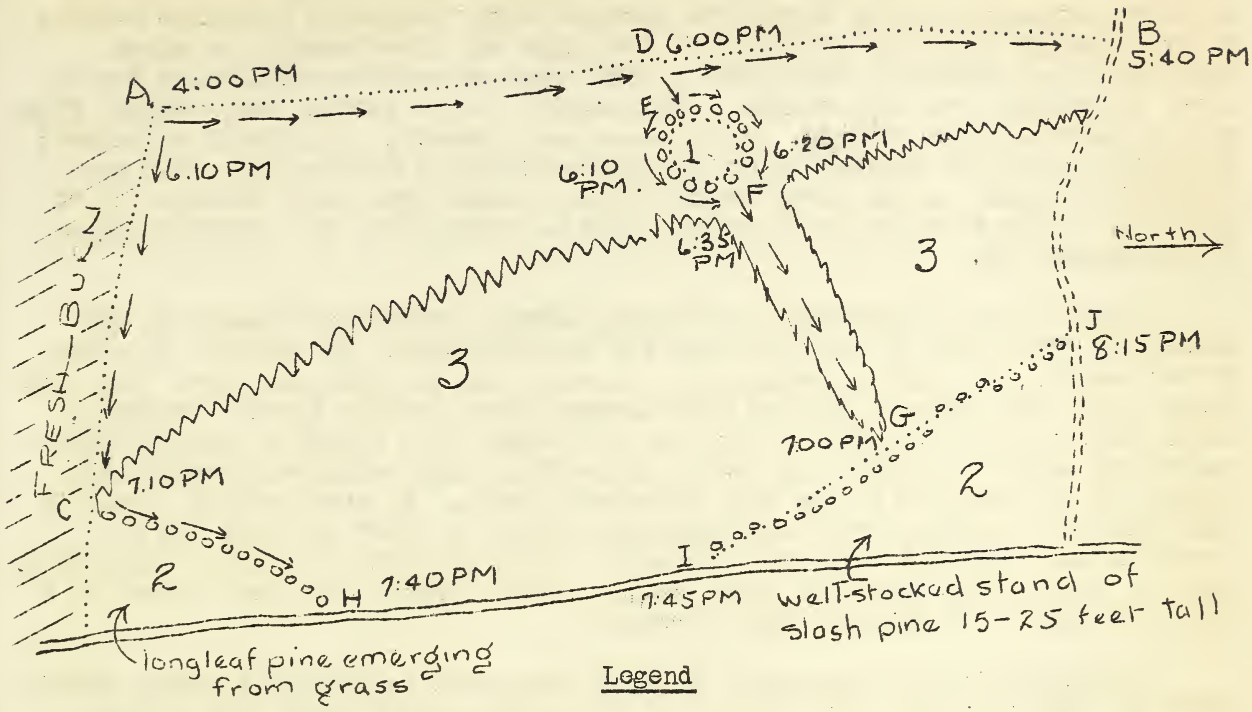
A preliminary examination which selects the area to burn and tentatively subdivides it into burning units is recommended. The primary considerations in selection are the over-all pattern, continuity of the network, ease of burning, and anticipated benefits. Usually, islands or blocks where proper use of fire would have a high insurance value should be selected first and subsequently connected by strips through areas that are easy to burn. As the examination proceeds, approximate burning unit boundaries should be sketched on the map. Size of burning units will vary widely but about 10 acres is the minimum.

After the area to burn has been selected, a detailed sketch map and description of each burning unit, showing boundaries, location of firebreaks, special problems of burning or protection, and classes of area should be made. Revision of the burning unit boundaries may often be necessary to increase uniformity or to provide a more efficient work unit. The mapper should imagine that he is burning each unit examined and attempt to solve the problems of the burning crew. Uniformity of fuel and stand throughout a burning unit is desirable, but the patchy, uneven condition of present stands often makes this difficult or impossible. Major irregularities within burning units must be recognized and mapped for the guidance of the burning crew. Marking the outside boundaries to guide the burning crew after dark has been found desirable by at least one operator.

The sketch map is the final record of this examination. This map should show size and shape of the unit, location of all firebreaks, detailed fuel and stand classes—in short, all the information needed for planning the burn and managing the fire. Excessive detail should be avoided, but all usable information should be shown. For general guidance, 1 acre is recommended as the smallest practicable unit in mapping stand variations.

A burning plan is prepared for each unit from the sketch maps. These plans should be positive, simple, clear, and brief. A sketch map on a single letter-size sheet with instructions below is a desirable form for these plans. The instructions should specify: (1) additional firebreaks needed, exterior and interior; (2) size of crew and duties of each member; (3) equipment and tools necessary; (4) season and time of day to start the burning; (5) wind directions under which to start the burning; (6) other important weather elements; (7) point or points at which to start the burning; (8) direction and rate of spreading fire; (9) provisions to meet changed burning conditions. Figure 2 illustrates a plan for a burning unit. These are suggestions to the crew leader to guide him in his burning; he must also use judgment to revise this plan to meet conditions actually encountered.

Fig. 2. A burning unit map and plan for southeastern flatwoods.



Legend

graded dirt road
woods road
lines to prepare before burning
fuel-stand class boundaries
direction, timing, and position of spreading
estimated position of fire at 7 p.m. when straw boss has reached point G.

Fuel-stand classes:
1-burning undesirable
2-burning difficult
3-burning easy

BURN ON NE WIND

Instructions

Start at A, 2 hours before sunset, and spread fire northward 50 chains to B, 1 man spreading, 2 men patrolling. One man stays at B to advance along woods road with fire. One man returns to A, spreads fire 15 chains to C, then burns area of young longleaf with a backfire after dark. Third man (straw boss) returns to D, spreads fire NE to E, thence to F, first north then south of small slash pine, then NE from F to G. Straw boss joins man at C, with him spreads fire to H, extinguishing westerly flank. Straw boss returns to I, spreads fire to J to burn out area of 15'-25' slash pine, then replaces man left at B who mops up as needed from B to A. Unit burns out about midnight.

Timing of Operations

Season of the year, time of day, and weather conditions are all-important in the effective use of fire. During the winter season the pines become dormant and less liable to damage; at the same time the herbaceous fuels die and cure. For most purposes, burning during the dormant winter season is desirable because of the lessened liability of injury to the pines and also because the cured herbaceous fuel permits burning over a wide range of moisture conditions (up to about 65 percent oven-dry weight). Occasionally, as in seedbed preparation, fire will be used at other periods. These cases are, however, exceptional and should generally be avoided because of the greater activity of barkbeetles. The most appropriate season in the lower Coastal Plain extends from about November 15 to March 15. Where practicable, burning should be confined to the period December 15 to February 28.

Time of day is important in planning burning operations because of the associated variations in fuel moisture and wind behavior. At sunrise, in clear winter weather, the fuel is ordinarily saturated and the wind very low. The wind rises as the day advances and the fuel becomes progressively drier. Shifting, gusty winds during the middle of the day are common as a result of unequal heating of the earth's surface. As sunset approaches, wind conditions become more stable and the moisture of the fuel increases slowly. At about sunset a lull in wind velocity is common; the wind ordinarily picks up after the lull and is steady in direction and velocity, gradually losing strength as sunrise approaches. Near the coast, wind direction often changes about sunrise and about sunset as a result of unequal heating of land and water.

Although fire can frequently be used throughout the daylight hours, conditions are most favorable from an hour or two before sunset until 3 to 4 hours before sunrise. Backfires should ordinarily be completed by dark, to gain advantage of the better visibility. Burning during the night can often be speeded by the wise use of flank fires, a practice discussed in the next section.

In general, moderate wind velocities of 5-10 miles per hour are preferable to lower velocities or a calm or to an excessively high wind. The major advantage of a moderately high velocity is its constancy, such winds having less variation in both direction and velocity. An added advantage is that higher winds on a backing fire dissipate the heat evolved more quickly, thus preventing the rising of hot blasts of air to defoliate the trees immediately above the flames. Steady winds of relatively high velocities are especially desirable in treating difficult areas, such as young dense stands of slash pine where damage under light and variable winds may be extensive. Excessively high wind velocities should also be avoided because of the danger of the fire escaping.

Throughout this region northerly winds are most stable, both in direction and in velocity, and are to be preferred in difficult operations. A recurring cycle of weather conditions is discernible throughout the Coastal Plain during these winter months. Warm cloudy days with variable southerly winds, frequently accompanied by rain, are followed by a period in which clear skies, cold nights, and steadier northerly winds are in prospect for about 3 days. This period of northerly winds is the preferred time for using fire on a hard chance. While burning under steady northerly winds is preferred, successful work can ordinarily be accomplished at other periods. Burning under other wind directions or with light and variable winds is definitely more risky and should be confined to small, less difficult burning units.

The limited number of days available for burning during the dormant season should be recognized in planning. Experience has shown that 3 or 4 days a week are ordinarily suitable for such work, Sundays excluded. Burning is usually possible from an hour or two after a rain until it rains again. Weather records for Florida and Louisiana over the past 50 years show that, on an average, there are 64 week-days suitable for this work in Florida and 52 days in Louisiana from mid-November to mid-March. In planning for any particular year, it would be conservative to discount these numbers to 55 and 45 days respectively.

Preparations for Burning

Preparations including maps and burning plans by units should be completed well in advance of the actual burning. It is usually desirable to plow lines around the boundaries of units, and to protect interior patches of small vulnerable pine. Existing breaks should be used as much as possible to keep the cost of this item small, but most use of fire will require some firebreak preparation.

In addition, one or more crews should be assembled and trained to carry out the work planned. Each crew should consist of 2-5 men under an experienced and qualified leader. All members of the crew should be thoroughly instructed in the purposes and objectives of the operation and in the part which each will play. Frequently it will be necessary to proceed slowly with the initial burning in order to train the crew members adequately in their respective jobs.

Adequate equipment should be assembled to provide not only for the actual burning operation but also for emergencies requiring fire suppression. Most of the actual firing will ordinarily be done by 1 or 2 men, but all should be equipped to spread fire. A rake with a long metal shank is an adequate backfiring tool; simple kerosene torches made from iron pipe have also been used effectively. Helpers will ordinarily be equipped mainly with flaps for stopping breakovers, but it is desirable to have other hand equipment available for emergencies. Below is a suggested list of such equipment for a 5-man crew:

Backfiring rakes	3-5
Torches	1-2
Flaps	5
Axes	2
Saws, crosscut	1
Backpack fire pumps	2
Shovels, round point	3
Fire rakes, Council or similar	1
Matches	

All equipment should be adequately housed and stowed on a pick-up truck.

Tractor-drawn plows and light pick-up trucks are desirable equipment on any burning job. The plowing of a certain amount of line is necessary to an effective job and either animal- or machine-drawn equipment may be used. Ordinarily plowing should be done ahead of the burning job; it is usually desirable to have preparations complete by about December 1. The use of plows should be restricted, because of the cost of operation, to the minimum amount necessary to provide adequate control on the burning units. Otherwise the costs of plowing may result in an expensive operation.

In addition to their use in preparation of units, the fireline plows provide a measure of insurance on burning operations. In case of breakovers or abrupt wind shifts, these units are a most effective method of controlling fires. Where available, plow units should be present on jobs to provide protection against such unexpected occurrences. A pick-up or other light truck equipped with power pump and water can also be used effectively in insuring against serious threats to the stand.

Weather governs fire behavior and wind is the most important single factor in the successful use of fire. Before starting to burn, therefore, weather conditions should be carefully studied in selecting the unit to burn. The limited forecasts available during the war period are of little value in planning; later, special arrangements for weather forecasts may be made. Current wind and rainfall records can frequently be maintained and consulted to improve the burning job. Experience with burning will gradually develop skill in anticipating changes in wind velocity and direction.

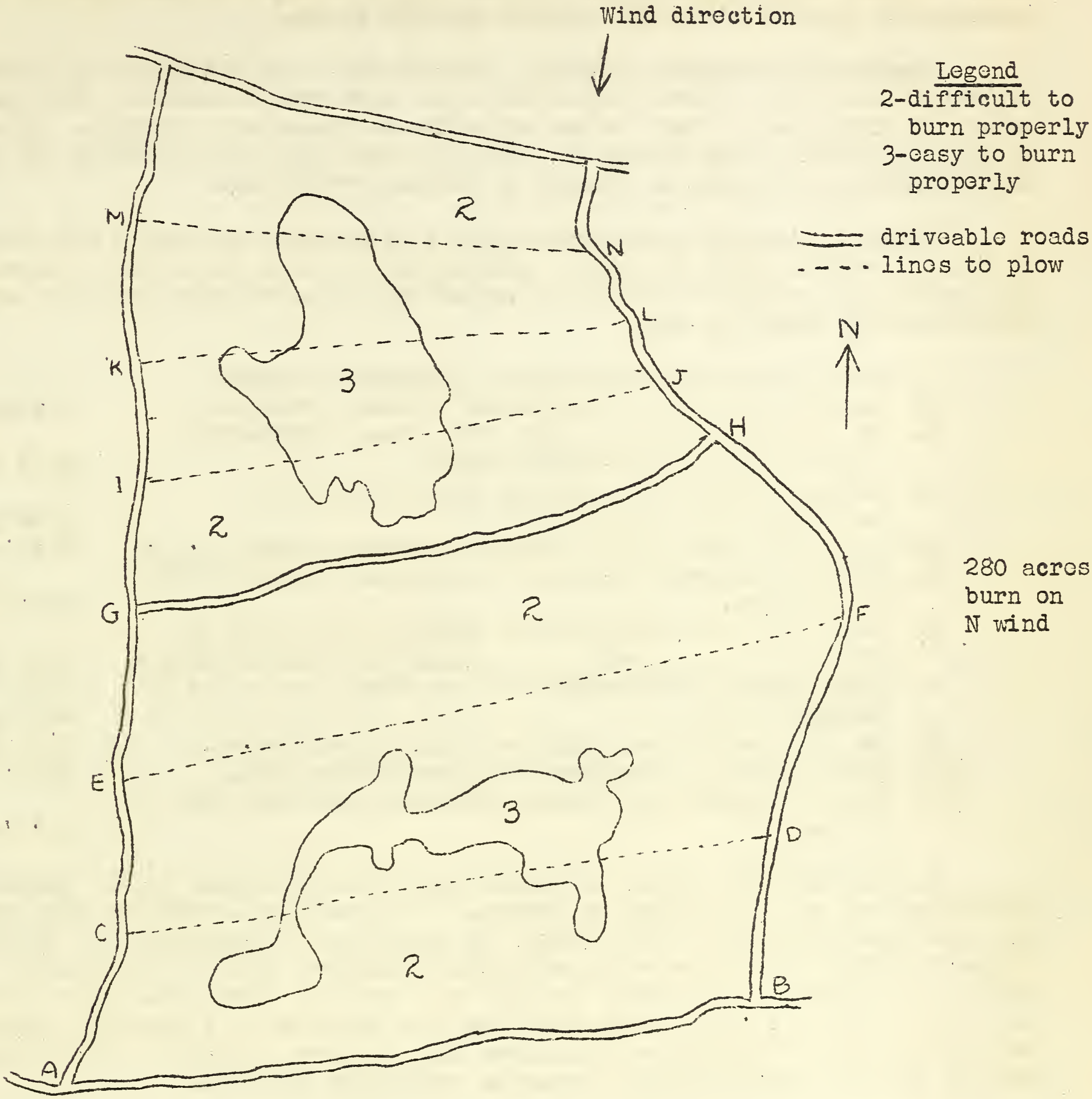
Burning Operations

With sufficient preparation, the job of burning should offer no particular difficulty to a trained and experienced crew. The first step is to establish a backfire along the leeward edge of the unit; the second is to extend the flanks to create a bow-shaped line of fire with the open end toward the wind. These two steps are usually followed by patrol and mop-up until the unit has burned over and is safe to leave. In an herbaceous fuel, backfires usually advance about a foot per minute; flank fires move appreciably faster, depending upon their angle with wind direction and upon wind velocity. Since there is ordinarily little difference in scorching, flank fires should be used to lower costs except where abundant fuel or fire-sensitive pine demands the lightest possible fire.

In burning units with a high length-to-width ratio, it is often desirable to spread lines of fire from the backfire into the wind across the unit to hasten the burning. Sometimes, particularly late at night, burning with the wind may be appropriate; costs are markedly reduced, but in most stands, the resultant injury vetoes its use. On units where only backfires are prescribed, plowed lines throughout the unit, thus permitting the use of two or more parallel lines of fire, perpendicular to the wind direction, will greatly expedite the job. Figure 3 illustrates burning a unit under this plan.

Mop-up and patrol are important here as on wildfires. Their proper use helps reduce the costs of burning and damage. Patrol begins as soon as the backfire is started and ends when all danger of escape has passed, but it need not be continuous. Mop-up should begin as soon as a man can be spared from establishing the backfire and should be concerned only with real threats to a breakover, snags and other sizeable burning objects close to the line. Once the back and flank fires are secure, continuous patrol is no longer needed. A morning check-up, however, starting 2-3 hours after sunrise, is a necessary part of safe practice.

Fig. 3. Illustration of simultaneous use of two or more parallel lines of backfire in burning unit under stand conditions requiring burning entirely against the wind.



Instructions

1. Plow lines: CD, EF, IJ, KL, and MN before burning.
2. Assemble 5-man crew at A at 4 p.m.
3. Leader explains plan to crew.
4. Spreading starts from A, C, and E at 5 p.m. with leader at A and 2 men at C and E, reaching B, D, and F at about 6 p.m.
5. One of men at D replaces leader at B and leader goes to G checking fire en route.
6. One of men at F goes to H and spreads fire toward G, meeting leader near G. 7 p.m.
7. Leader proceeds to I and spreads line IJ and is met by men left at B and D at 7:30 p.m.
8. Leader and 1 man spread lines KL and MN, complete at 8 p.m.
9. Crew mop up and patrol until 4 a.m. when fire is burned out.

Patience is the outstanding characteristic of the man who uses fire successfully. The job is slow and unspectacular. It involves long hours of waiting under some discomfort while a slow fire leisurely progresses across a unit. Without such patience, the foreman may, however, save time only at a considerable loss of young and valuable growing stock.

Alertness to changing weather, particularly to shifting winds, is another characteristic of the successful foreman. He must judge accurately the speed and safety of firing and he must detect and suppress breakovers promptly. As shifts in wind directions occur he must be able to change his plans promptly and otherwise adjust the operation to changes in burning conditions.

Figure 1 illustrates the burning of a particular unit where the execution of the job conforms with the plan. Actually the plan is frequently changed by the foreman as a result of shifts in conditions. The ordinary steps in burning, illustrated in figure 2, are:

1.	Notify adjacent landowners of intention to burn.	
2.	Assembly of crew at designated starting point A.	4 p.m.
3.	The foreman discusses plans with crew, instructing each man in his individual duties.	4:15 p.m.
4.	Burning conditions tested by observation of a small spot fire (optional).	4:30 p.m.
5.	Spreading starts from selected starting points ____.	5 p.m.
6.	Backfire is pushed through to completion before dark if possible.	6:45 p.m.
7.	Later, and with satisfactory winds, flank fires are spread at _____ and _____ along the external lines.	7:30 p.m.
8.	Where needed, supplementary flank fires may be set in internal lines.	7:40-8:15 p.m.
9.	As work progresses, burned-out line is mopped up.	7-11:30 p.m.
10.	Final mop-up is completed and crew leaves fire.	11:45 p.m.
11.	Fire is checked by a fresh patrolman not later than 8 a.m.	6-8 a.m.

In following the above, the leader must depend largely on his judgment in placing men and in deciding on action. Local weather conditions will govern the speed and efficiency of the work. As experience is acquired, the skill and judgment of the entire crew will grow until decisions will be made quickly and easily in response to variations in fuel and weather. Fire skillfully applied can never become a routine task, however. Its behavior is frequently surprising and never wholly predictable. Foresters have in fire a flexible and valuable tool if they can anticipate its vagaries and master its uses.

Every day's operation should be critically reviewed; mistakes and failures should be analyzed to prevent similar occurrences on other operations. Although final judgment of the success of the job will depend upon examination some weeks after the burning, certain damage will be obvious at the time of the burn. Often such damage can be prevented on succeeding units by planning and particularly by skillful laying of the fire.

Judging Results

The use of fire is recommended only where a careful analysis has shown the assumed benefits are clearly greater than the assumed losses and costs. Following the burning, a second analysis is desirable to better gage both benefits and losses. In the illustration on page 9 of this paper, the benefits and losses are compared. After the burning a similar analysis should be made using corrected costs and estimates of damage based on field examinations.

In judging the degree of success attained, the objectives of burning should be considered, and the degree to which they have been reached: Have fuel accumulations been reduced? Has a satisfactory barrier to fire spread been established? Have other objectives in the burning been attained?

Costs of the operations should also be analyzed carefully. During the first few weeks of burning, costs will often be high. Have costs been excessive in proportion to the benefits obtained through the use of extra men and special preparations? Can they be reduced without increasing damage to the point of eliminating the savings? How can costs on next year's operations be lowered?

Injuries to the stand should be determined through examination of an adequate sample. Estimates of defoliation and seedling and other mortality should be made. An experienced forest manager will not find the necessary cruising a difficult task, and the resulting data will be most helpful in guiding future work. All areas should be sampled representatively to get an appraisal in which both poor and good results are present.

No arbitrary value can be placed on seedlings killed. Their value is largely dependent on their position in the stand and the prevalence of other seedlings in the same locality. Slash pines remote from an existing seed source, for instance, are more valuable than trees of the same size and type where slash pine seed is abundant; likewise dominant, well-spaced trees have a higher value than crowded or understory trees.

Defoliation results in certain growth losses. Below the limit of one-third the crown, little loss has been measured. Above this point loss in growth is about in proportion to loss of foliage with total defoliation roughly equal to loss of 1 year's growth. By this rule, loss of two-thirds of the foliage would result in approximately half the normal increment in the stand for 1 year.

SUMMARY

In this paper, the principles governing the use of fire in the protection of longleaf and slash pine forests have been discussed and a general procedure for deciding on the wisdom of burning, and for planning and executing plans for fire use, has been described. The desirable steps in this procedure are: (1) An analysis to determine the desirability of use of fire; (2) the selection of a general plan or pattern of area to be treated; (3) an examination to locate burning units within this pattern; (4) the preparation of a sketch map for each burning unit; (5) the preparation of detailed plans for treating each unit; (6) treating the units as prescribed in the plans; (7) a critical review of the burning and its results.

In these recommendations, particular emphasis is placed on the analysis and planning of fire use. Voluminous paper work is undesirable, and the amount of detail should be kept to a minimum. It should be recognized, however, that the success of fire use depends principally upon a detailed knowledge of fuel and stand conditions. Frequently this phase of a successful program will require more time and energy from the supervisor than will the actual burning operation. Only by such analysis and preparation will the use of fire become a pointed and effective tool in the management of forest land in the longleaf-slash pine region.